Chapter 5
Zooplankton and Mysid Shrimp, 2001-2002

Mysid shrimp and zooplankton are important food organisms for larval, juvenile, and small fish, such as delta smelt, juvenile salmon, striped bass, and small splittail. The *Neomysis*/Zooplankton Study investigates the annual population level of *Neomysis mercedis*, other mysids, and various zooplankton species and genera in order to assess the size of the food resource for fish. The study also seeks to detect the presence of exotic species recently introduced to the San Francisco Estuary (Estuary), to monitor the distribution and abundance of these exotics, and to determine their impacts on native species. The study began to monitor *N. mercedis* in June 1968 and was expanded to include copepods, cladocera, and rotifers in January 1972.

Methods

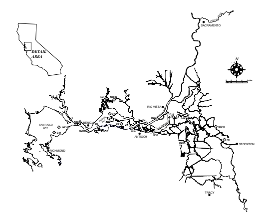

Figure 5-1 Zooplankton monitoring stations

Macro-, meso-, and micro-zooplankton were sampled monthly at 15 to 20 stations in the Delta and Suisun Bay (Figure 5-1). Eighteen of these stations were at fixed geographic locations. Two additional stations were identified as existing at the points where the bottom electrical conductance was 2 and 6 millisiemens per centimeter (mS/cm) respectively; these are considered "floating" stations. Additionally, one station in San Pablo Bay and two stations in Carquinez Strait were sampled only when their surface salinity was less than 20 mS/cm.

At each station three types of gear were deployed: a *Neomysis* net, (1.48-m long and with a 29-cm mouth diameter and a mesh size of 0.505 mm) mounted on a towing frame made of steel tubing, with a General Oceanics net meter at its mouth; a Clarke-Bumpus net for zooplankton (with a mouth diameter of 12.5 cm and a mesh size of 154 µm) that was mounted above the *Neomysis* net on the same frame as the first net; and a 15-liter per minute-capacity pump. At each station, while underway, the towing frame was lowered to the bottom and retrieved obliquely in several steps over a 10-minute period. Zooplankton small enough to pass through the Clarke-Bumpus net (mostly copepod nauplii, rotifers, and Oithonids) were sampled with the pump. At each station, the pump intake was lowered to the bottom, raised slowly to the surface, and then lowered and raised a second time. The pumped water was discharged into a 19-liter carboy that was shaken and then a 1.5 to 1.9 liter sample was decanted into a jug. All samples were preserved in buffered 10% formalin and returned to the laboratory for identification. Temperature and specific conductance were measured at surface and bottom, both before and after each tow, using a Seabird model CTD 911+ data logger that was lowered through the water column.

To calculate monthly abundance indices, the sample area was divided into the following three zones based on bottom specific conductance: (1) the entrapment zone (1.8 mS/cm to 6.6 mS/cm); (2) upstream of the entrapment zone (< 1.8 mS/cm); and (3) downstream of the entrapment zone (> 6.6 mS/cm). The density for each taxon was calculated as the number of organisms per cubic meter (org/m^3). Monthly abundance was calculated as the mean monthly density of each taxon in each zone. The number of stations in each zone varied from month to month based on upstream and downstream shifts in the salinity gradient. Although no species was present at all stations in every month, averaging the density by the total number of stations sampled in each zone provided a common and consistent base for comparing taxon densities. A grand mean abundance was calculated for each taxon in number per cubic meter of all stations sampled in 2001 and 2002. Abundance data were log transformed (log10(abundance+1)) before they were plotted to improve interpretation by reducing variability from month to month.

N. mercedis has been identified and counted since 1968 and *Acanthomysis bowmani* since 1994. Identification and counting of the other five mysid species (*A. aspera, A. hwanhaiensis, A. macropsis, Deltamysis holmquistae,* and *N. kadiakensis*) became standard operating procedure in 1998.

For brevity, zooplankton were divided into the following four groups: calanoid copepods, cyclopoid copepods, cladocera, and rotifers. The trends of the three or four most abundant taxa in each group are presented in this report.

Results

The mean monthly densities of most of the taxa discussed remained stable throughout 2001 and 2002. Only the mysids *N. kadiakensis* and *N. mercedis* declined from 2001 to 2002. The mean densities of the mysid *A. hwanhaiensis* and the calanoid copepod *Acartia* spp. increased slightly.

The years 2001 and 2002 were characterized by changes in the relative abundance of mysids and calanoid copepods in the upper Estuary. Generally, native species were less abundant in 2002, relative to introduced species, than in 2001. Once the dominant mysid of the upper Estuary, *N. mercedis* has become rare and has been all but replaced by two mysid species. *A. bowmani* was introduced in 1988 and *N. kadiakenis* only occasionally came into the upper Estuary. *A. bowmani* has become the dominant mysid throughout the upper Estuary. *N. kadiakensis* has been increasing in relative abundance downstream of the entrapment zone and has been the second most abundant mysid species in the upper Estuary since 2001.

Acartia spp. is the only calanoid copepod that has remained relatively dominant through time within the upper Estuary. A year after its introduction in 1988, *Pseudodiaptomus forbesi* became the dominant calanoid, thus replacing *Sinocalanus doerrii*, which had replaced earlier *Eurytemora affinis* as the dominant calanoid. In 2001, *Acartiella sinensis* became the third most dominant calanoid, thus reducing *E. affinis* to the lowest rank it has held since it was first counted by the project.

Mysids

A. bowmani (grand mean abundance = 9.257) was the most abundant mysid in all areas in 2001 and 2002 (Figure 5-2). *A. bowmani* abundance was highest in the entrapment zone and downstream of the entrapment zone. Peak *A. bowmani* abundance occurred from May through November 2001 and from May through September in 2002, except downstream of the entrapment zone where the peak abundance period lasted through November.

Figure 5-2 Monthly *Acanthomysis bowmani* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

N. kadiakensis (grand mean abundance = 0.153), the second most abundant mysid, was found primarily downstream of the entrapment zone, with few found within and very few found upstream of the entrapment zone (Figure 5-3). Downstream of the entrapment zone, peak abundance occurred in April through September. Except for July to September, *N. kadiakensis* was less abundant in 2001 than in 2002 downstream of the entrapment zone. *N. kadiakensis* abundance has been steadily increasing in the upper Estuary since 1998. In 1998, *N. kadiakensis* was the fourth most abundant mysid overall. In 1999 it was the third most abundant, and since 2001 it has been the second most abundant mysid in the upper Estuary.

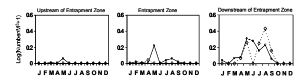

Figure 5-3 Monthly *Neomysis kadiakensis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

N. mercedis (grand mean abundance = 0.055), the third most abundant mysid, was caught primarily upstream, as well as inside, of the entrapment zone. Peak *N. mercedis* abundance occurred in May and June in 2001 and 2002 (Figure 5-4). The abundance of *N. mercedis* has been declining steadily since the introduction of *Potamocorbula amurensis* in 1989; the 2001 and 2002 levels are the lowest on record. *N. mercedis* was virtually absent downstream, as well as inside, of the entrapment zone in 2002. Prior to about 1996, the native mysid *N. kadiakensis* was found almost exclusively downstream of the sampling area; however, in 2001 and 2002 it appears to have taken *N. mercedis*' place as the second most abundant mysid in and downstream of the entrapment zone.

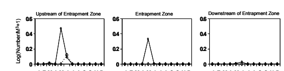

Figure 5-4 Monthly *N. mercedis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

The fourth most abundant mysid, *A. hwanhaiensis* (grand mean abundance = 0.033), occurred almost exclusively downstream of the entrapment zone and was abundant only in 2001 (Figure 5-5). Peak *A. hwanhaiensis* abundance occurred in December 2001.

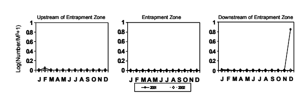

Figure 5-5 Monthly *Acanthomysis hwanhaiensis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

Calanoid Copepods

The native *Acartia* spp. (grand mean abundance = 306) was the most abundant calanoid copepod in the upper Estuary. It occurred primarily downstream of the entrapment zone (Figure 5-6). *Acartia* abundance was high downstream of the entrapment zone from January through June, with peak abundance from March through May and minimal abundance occurring from August through November. *Acartia* abundance was higher in all three zones in 2002 than in 2001. During winter and spring 2002, *Acartia* was found in greater than normal numbers just upstream of and in the entrapment zone.

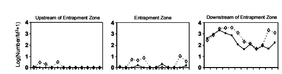

Figure 5-6 Monthly *Acartia* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

The introduced *Pseudodiaptomus forbesi* (grand mean abundance = 285) was the second most abundant calanoid copepod in the upper Estuary during 2001 and 2002 (Figure 5-7). *P. forbesi* abundance was greatest upstream of the entrapment zone and almost as high in the entrapment zone. In 2001, peak *P.*

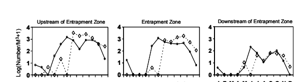

Figure 5-7 Monthly *Pseudodiaptomus forbesi* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

forbesi abundance was from May through November in all areas. In 2002, peak *P. forbesi* abundance was from July through November in all areas, with an early spike in May.

The third most abundant calanoid copepod was the introduced *Acartiella sinensis* (grand mean abundance = 148) (Figure 5-8). The highest concentrations of this copepod were found in and downstream of the entrapment zone, although large numbers were also found upstream of the entrapment zone. *A. sinensis* abundance showed a definite annual cycle; the annual low was in May or June and the annual high was in October. This cycle was observed in all three zones for both years.

Figure 5-8 Monthly *Acartiella sinensis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

Another introduced species, *Sinocalanus doerrii* (grand mean abundance = 106) was the fourth most abundant calanoid copepod (Figure 5-9). *S. doerrii* abundance reached high levels upstream of and in the entrapment zone. Its abundance started to increase in April and peaked in May or June. By July, *S. doerrii* abundance declined to a base level where it remained generally stable for most of 2001 and 2002.

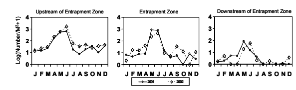

Figure 5-9 Monthly *Sinocalanus doerrii* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

Cyclopoid Copepods

Limnoithona tetraspina (grand mean abundance = 11,176) has been the most abundant cyclopoid copepod since its introduction in 1994 (Figure 5-10). *L. tetraspina* was abundant in all three zones, but was most abundant in and downstream of the entrapment zone. The abundance pattern was similar for both 2001 and 2002. Beginning in January of both years, abundance in all three areas tended to increase gradually until September or October and then drop toward the January level.

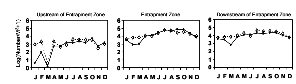

Figure 5-10 Monthly *Limnoithona tetraspina* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

The introduced *Oithona davisae* (grand mean abundance = 293) was the second most abundant cyclopoid copepod and occurred primarily downstream of the entrapment zone (Figure 5-11). *O. davisae* was also abundant in the entrapment zone and occurred sporadically upstream of the entrapment zone. Downstream of the entrapment zone, high abundance occurred from July through January, followed by a decline in February and March and a sharp dip in April of 2001 and 2002. In the entrapment zone, the abundance peak occurred in July in both years. In 2001 there was another smaller peak in March. Upstream of the entrapment zone, *O. davisae* abundance was generally low except for a sharp peak that occurred in October of 2001 and 2002.

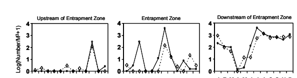

Figure 5-11 Monthly *Oithona davisae* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

The native *Acanthocyclops vernalis* (grand mean abundance = 23) was the third most abundant cyclopoid copepod. It was abundant throughout the sampling area, but declined from upstream of the entrapment zone to downstream (Figure 5-12). Its abundance peak was from February through July or August, with a secondary peak in the fall that varied in timing among the three zones.

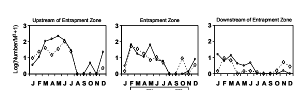

Figure 5-12 Monthly *Acanthocyclops vernalis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

Cladocera

Bosmina longirostris (grand mean abundance = 293) was the most abundant cladoceran in the upper Estuary in 2001 and 2002 (Figure 5-13). It was abundant throughout the year upstream of the entrapment zone, with a

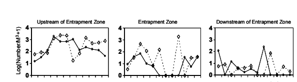

Figure 5-13 Monthly *Bosmina* spp. abundance upstream. in, and downstream of the entrapment zone, 2001 and 2002

nominal peak from April through June in 2001 and April through July in 2002. *B. longirostris* was absent from the entrapment zone from June through September in 2001 and in July and August in 2002, but was present for the remainder of those years. Its presence downstream of the entrapment zone was variable and it was not detected for several months in either 2001 or 2002.

Daphnia spp. (grand mean abundance = 118) was the second most abundant cladoceran for 2001, but was third most abundant for 2002. It was most abundant upstream of the entrapment zone where its peak abundance occurred from April through June in 2002 or April through July in 2001 (Figure 5-14). In the entrapment zone, *Daphnia* peaked from January through April of both years. Its abundance downstream of the entrapment zone was lower and more variable than in the other areas.

Figure 5-14 Monthly *Daphnia* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

Diaphanosoma spp., the least abundant of the identified cladocera for 2001 and 2002 (grand mean abundance = 103), was taken almost exclusively upstream of the entrapment zone (Figure 5-15). Peak abundance for this genus typically occurs from June through October and followed this pattern in 2001 and 2002. In the entrapment zone, *Diaphanosoma* was caught in low numbers from late spring until early fall of 2001 and 2002. *Diaphanosoma* rarely occurred downstream of the entrapment zone. However, in 2002, *Diaphanosoma* was the second most abundant cladoceran in the sampling area.

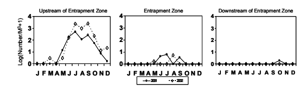

Figure 5-15 Monthly *Diaphanosoma* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

Rotifers

The genus *Synchaeta* (excluding *Synchaeta bicornis*) (grand mean abundance = 4,992) was the most abundant rotifer taxon (Figure 5-16). Although abundant in all areas, *Synchaeta* was slightly less abundant in the entrapment zone than the other two zones. Except for 2001, *Synchaeta* abundance dropped to zero in July and August both upstream and downstream of the entrapment zone. The peak abundance period for *Synchaeta*, as usual, began in October and continued through May of the following year. In the entrapment zone, abundance during the off peak period was variable.

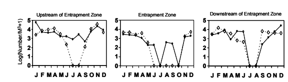

Figure 5-16 Monthly *Synchaeta* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

The genus *Polyarthra* (grand mean abundance = 3,599) was the second most abundant rotifer (Figure 5-17). It was most abundant upstream of the entrapment zone and least abundant downstream of the entrapment zone. Upstream of the entrapment zone, *Polyarthra* abundance remained fairly uniform throughout both years. Inside the entrapment zone, *Polyarthra* was abundant from January through April, but was very erratic throughout the rest of the year. *Polyarthra* was absent from the entrapment zone from July until November in 2001. In 2002 *Polyarthra* abundance varied considerably through the same period. Downstream of the entrapment zone, *Polyarthra* abundance was erratic, with several nominal peaks varying monthly from year to year.

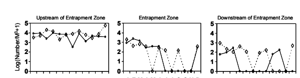

Figure 5-17 Monthly *Polyarthra* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

The third most abundant rotifer taxon was the genus *Keratella* (grand mean abundance = 3,087) (Figure 5-18). The highest *Keratella* abundance occurred upstream of the entrapment zone where there was an abundance peak from February through April or May (2001). Inside the entrapment zone during 2001, *Keratella* abundance varied from month to month. From February

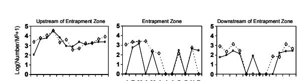

Figure 5-18 Monthly *Keratella* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

through April in 2002 there was a peak that coincided with the peak upstream of the entrapment zone. Thereafter *Keratella* abundance variations were similar to those in 2001. Downstream of the entrapment zone, *Keratella* was stable from January through April and from September or October through December, but was variable for the other months.

The fourth most abundant rotifer taxon was *Synchaeta bicornis* (grand mean abundance = 699) (Figure 5-19). This species was most abundant downstream of the entrapment zone and least abundant upstream of the entrapment zone. Its abundance upstream and downstream of the entrapment zone peaked in October of both 2001 and 2002; while inside the entrapment zone, its abundance peaked in July 2001 and August 2002.

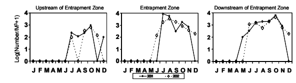

Figure 5-19 Monthly *Synchaeta bicornis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

Summary

The monthly abundance figures for most of the common zooplankton taxa in the upper Estuary were stable during 2001 and 2002, but *N. mercedis* and *N. kadiakensis* abundance declined during this period.

During 2001 and 2002, the abundance of native mysid and calanoid copepod species declined relative to that of introduced species. Prior to the introduction of *A. bowmani* in 1993, *N. mercedis* was virtually the only mysid species in the upper Estuary. In 2001 *N. mercedis* became the third most abundant mysid in the upper Estuary after *A. bowmani* and *N. kadiakensis*.

Figure 5-1 Zooplankton monitoring stations

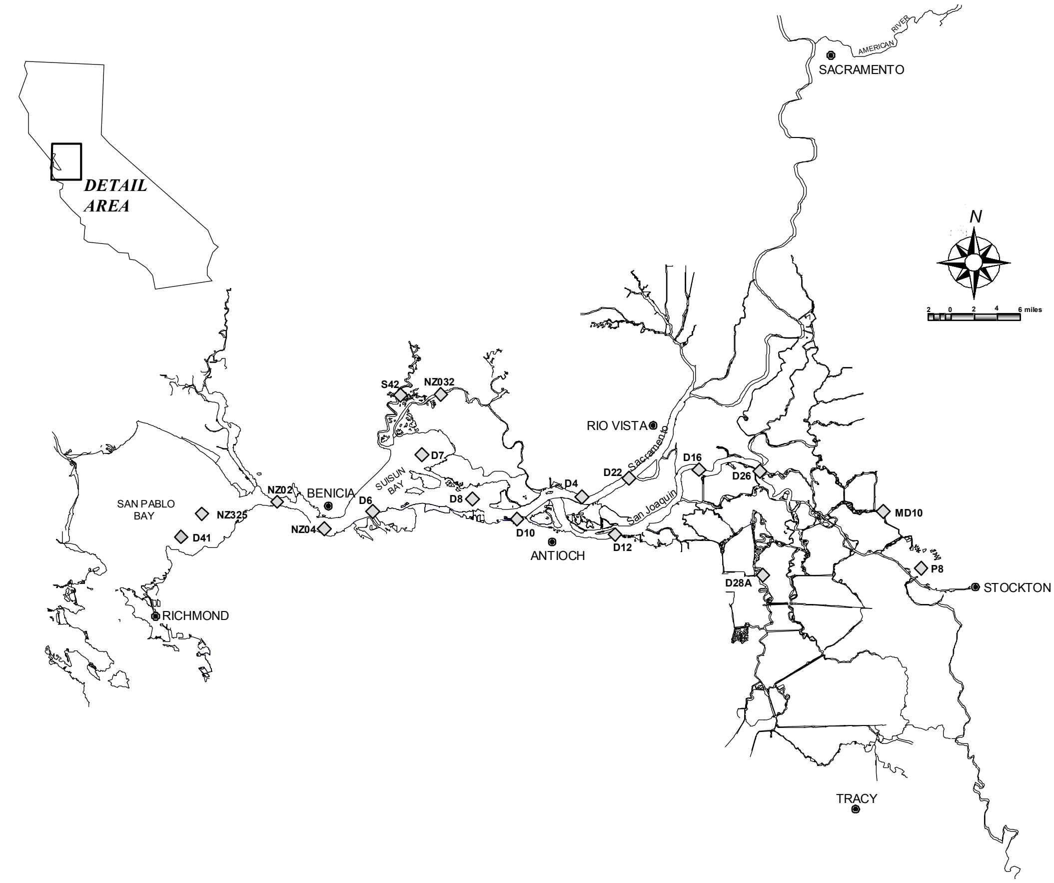

Figure 5-2 Monthly *Acanthomysis bowmani* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

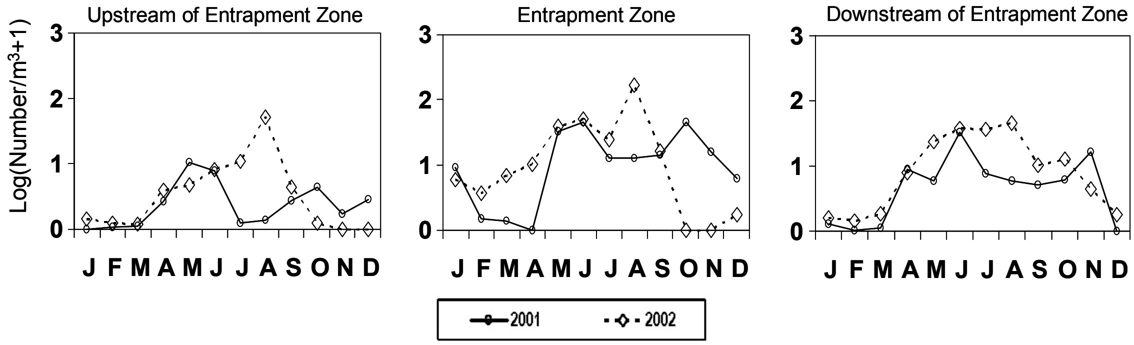

Figure 5-3 Monthly *Neomysis kadiakensis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

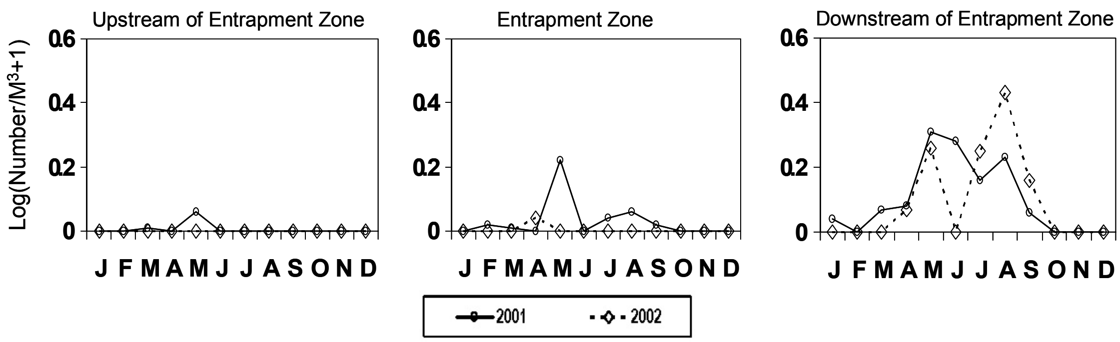

Figure 5-4 Monthly *Neomysis mercedis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

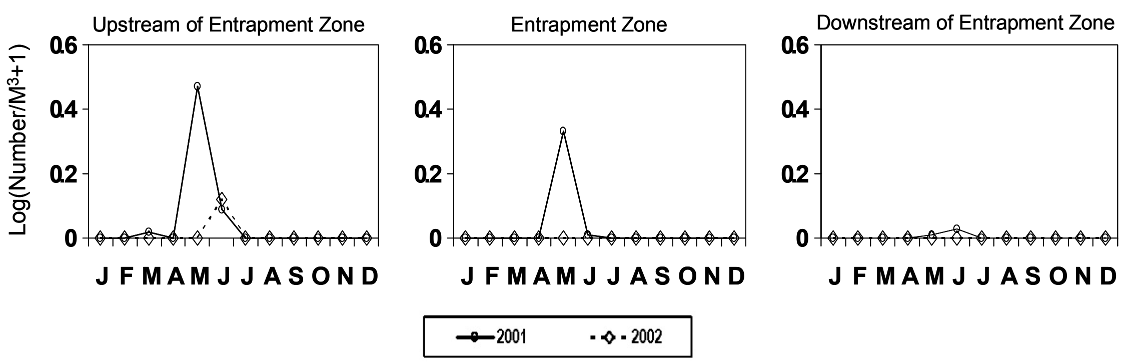

Figure 5-5 Monthly *Acanthomysis hwanhaiensis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

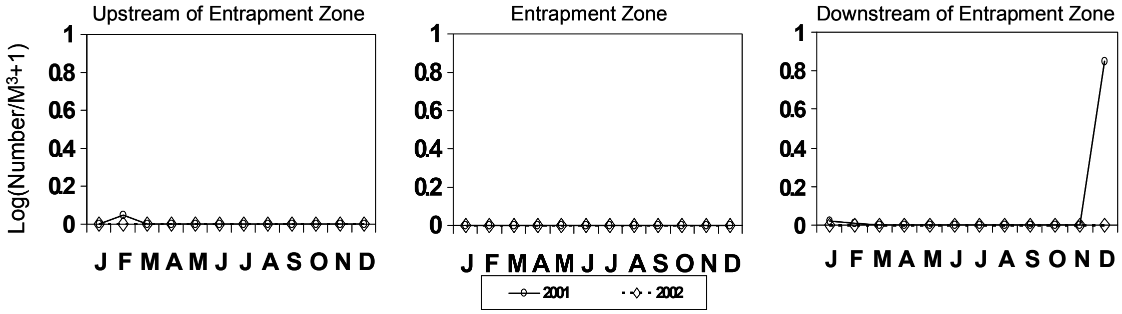

Figure 5-6 Monthly *Acartia* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

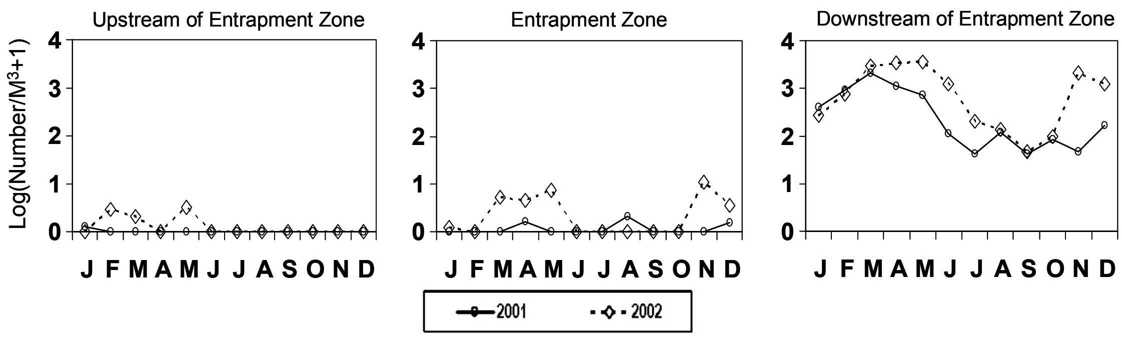

Figure 5-7 Monthly *Pseudodiaptomus forbesi* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

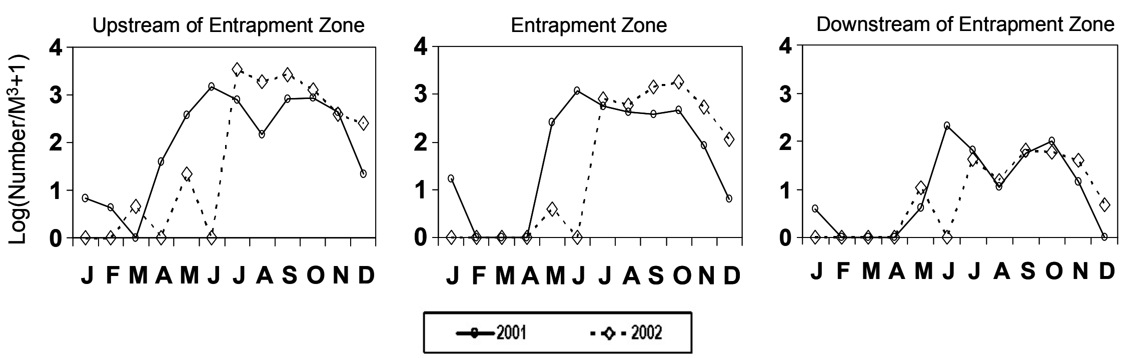

Figure 5-8 Monthly *Acartiella sinensis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

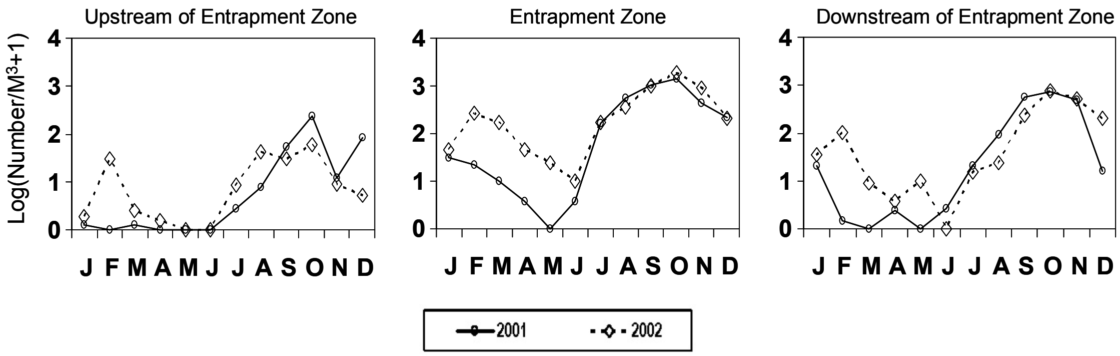

Figure 5-9 Monthly *Sinocalanus doerrii* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

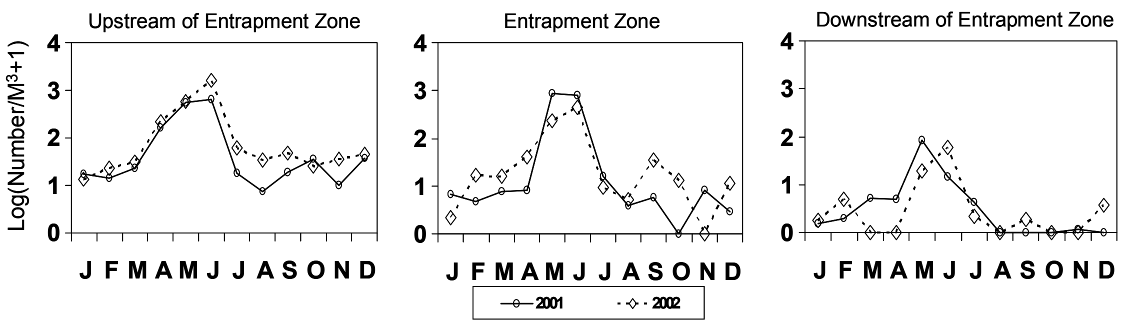

Figure 5-10 Monthly *Limnoithona tetraspina* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

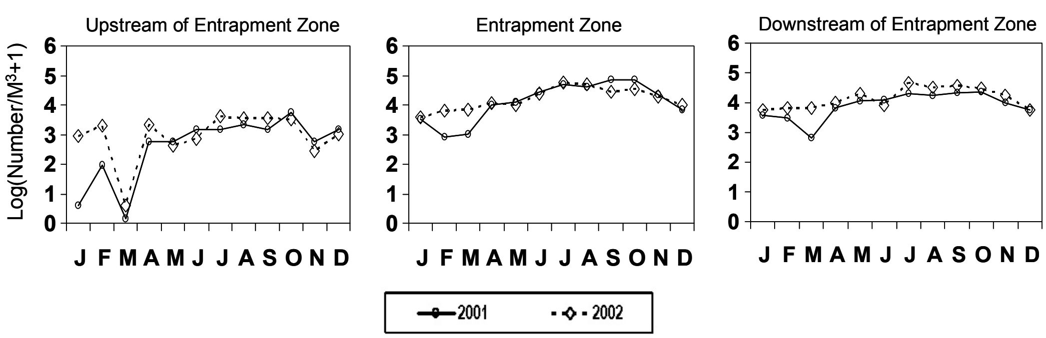

Figure 5-11 Monthly *Oithona davisae* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

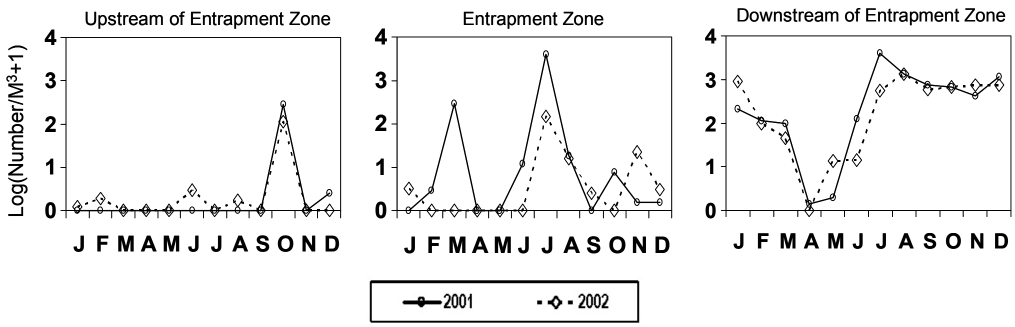

Figure 5-12 Monthly *Acanthocyclops vernalis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

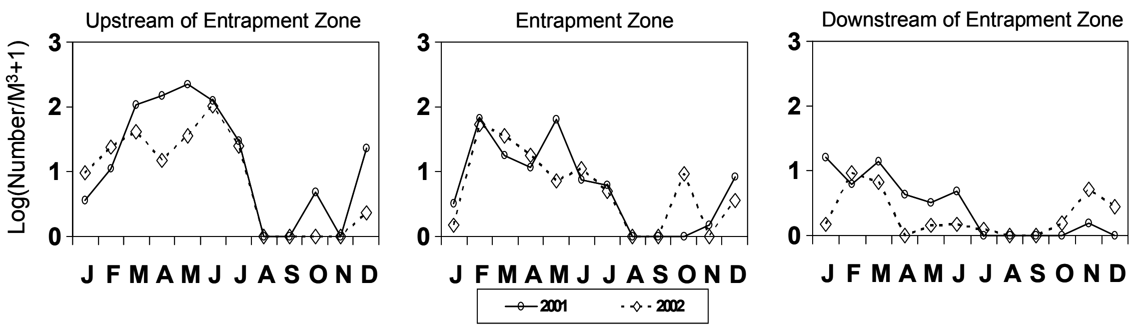

Figure 5-13 Monthly *Bosmina* spp. abundance upstream. in, and downstream of the entrapment zone, 2001 and 2002

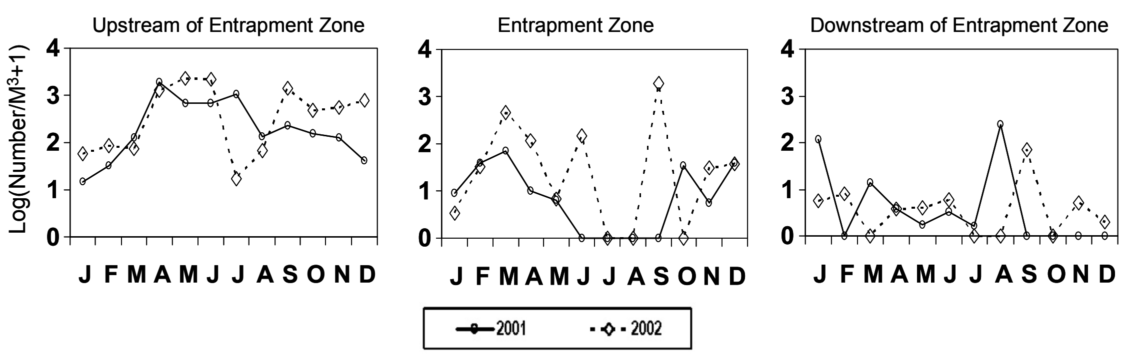

Figure 5-14 Monthly *Daphnia* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

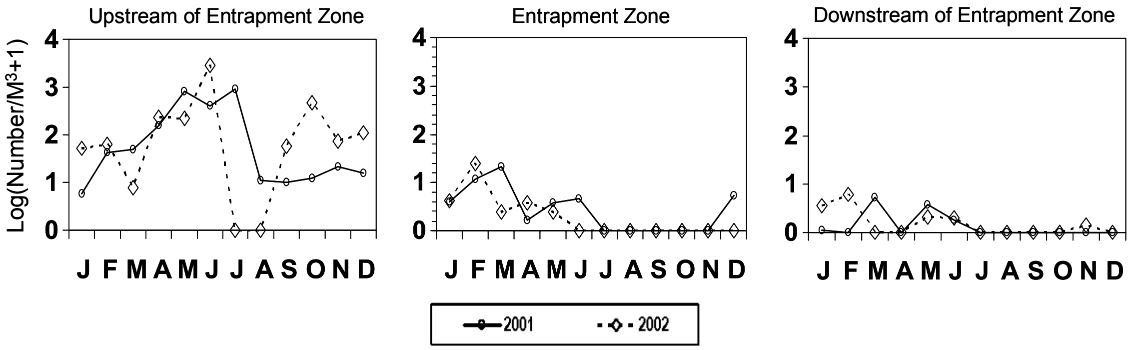

Figure 5-15 Monthly *Diaphanosoma* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

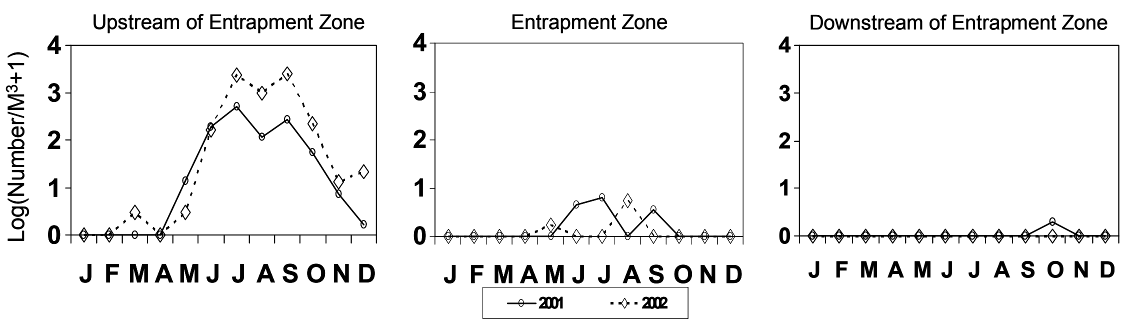

Figure 5-16 Monthly *Synchaeta* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

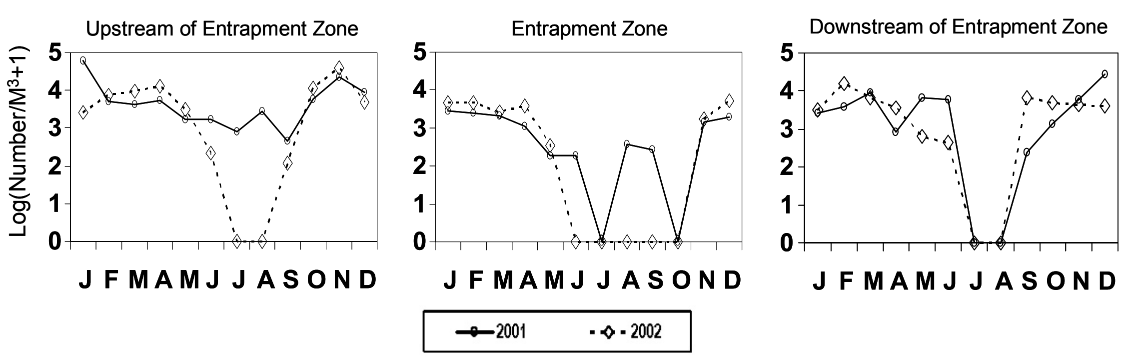

Figure 5-17 Monthly *Polyarthra* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

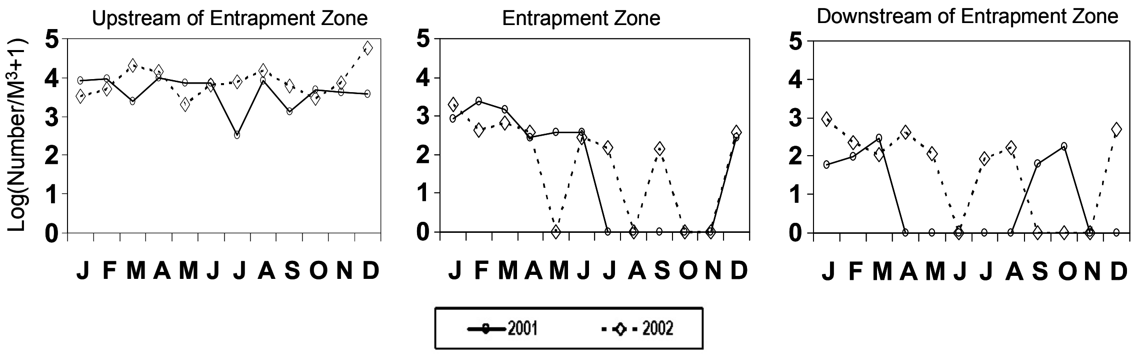

Figure 5-18 Monthly *Keratella* spp. abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002

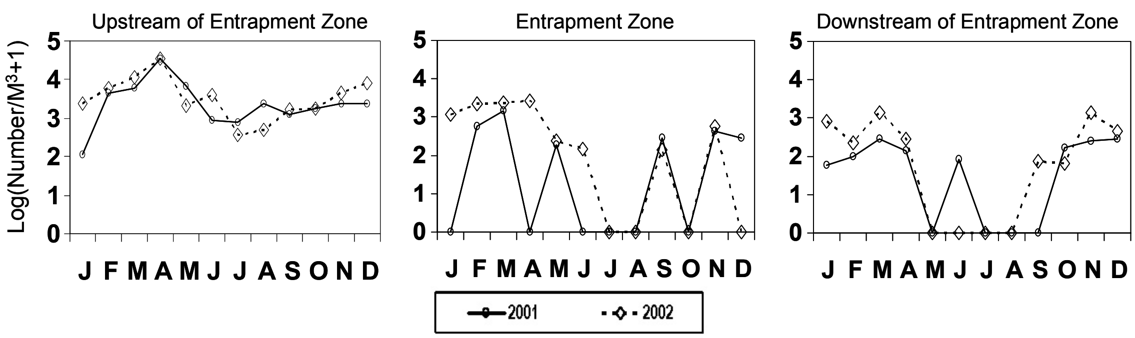

Figure 5-19 Monthly *Synchaeta bicornis* abundance upstream, in, and downstream of the entrapment zone, 2001 and 2002